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Seven-Year Experience with Ablation of Permanent Atrial Fibrillation Concomitant to Mitral Valve Surgery in 152 Patients

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ABSTRACT

Background. This study analyzed 7 years of results for monopolar endocardial radiofrequency (RF) ablation of permanent atrial fibrillation (pAF) concomitant to mitral valve (MV) surgery.

Methods. Between 2001 and 2007, 152 patients who had experienced pAF for a median of 4.0 years (interquartile range, 1.5-8.0 years; range, 0.5-33 years) underwent monopolar endocardial RF ablation procedures (pulmonary vein isolation plus a connecting lesion) concomitant to MV surgery. All patients were reexamined to assess survival, conversion rate to stable sinus rhythm (SR), and New York Heart Association (NYHA) class at 8 ± 1 days after surgery and follow-ups at 3 ± 1 months and 41 ± 24 months postoperatively. Data were analyzed exploratatively.

Results. The survival rates at the 3 reexamination times were 97%, 95%, and 92%, respectively (6 cardiac and 6 noncardiac deaths), and the corresponding SR rates were 74%, 75%, and 73%. The NYHA class of the patients improved significantly after surgery ($P = .006$), particularly when a stable SR had been achieved ($P = .039$). Long-term pAF prior to surgery and a larger left atrium (LA) preoperatively were predictive of the return of postoperative AF ($P = .0002$, and $P = .0003$, respectively). Ninety-one percent of the patients with a preoperative pAF duration of <5 years and 88% of the patients with an LA size of ≤55 mm were in stable SR at the late follow-up. The cardiac rhythm at discharge and 3 months after surgery were predictive of a prognosis of long-term rhythm ($P = .021$, and $P = .00002$, respectively). Age, sex, and the underlying etiology of MV disease did not have a significant influence on postoperative cardiac rhythm.

Conclusion. This study demonstrated that a SR established after combined pAF ablation and MV surgery remains stable over time. Preoperative LA size and pAF duration are useful parameters for evaluating the success rate of pAF ablation concomitant to MV surgery.

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INTRODUCTION

Permanent atrial fibrillation (pAF) can be a serious concomitant problem in patients with severe mitral valve (MV) disease [Benjamin 1998; Jessurun 2000; Geidel 2004]. The aim of this study was to evaluate early and late results of using monopolar radiofrequency (RF) ablation in patients with concomitant pAF who were scheduled for MV surgery. The data of 7 years of clinical experience are analyzed.

MATERIALS AND METHODS

The population of this prospective investigation consisted of a selected group of 152 consecutive patients who had severe MV disease and concomitant pAF for at least 0.5 years (median, 4.0 years; interquartile range, 1.5-8.0 years; range, 0.5-33 years) and who underwent combined MV and ablation surgery in our institution between February 2001 and September 2007. Monopolar endocardial RF ablation was performed in all 152 cases. The characteristics of the patients are summarized in Table 1. The exclusion criteria for concomitant ablation in other MV cases with AF during this period (n = 78) were as follows: other forms of AF (ie, not pAF for at least 0.5 years), emergency operation, a severely reduced left ventricular ejection fraction (≤25%), acute endocarditis or myocardial infarction (≤7 days), considerable cachexia (body mass index ≤18), and severe intracardiac thrombosis or an extremely large left atrium (LA) (diameter ≥72 mm). The etiology of MV disease was assessed from the patient's clinical history, intraoperative examination of the valve, and histologic analysis.

Technique of Combined MV and Ablation Surgery

After cardiopulmonary bypass and protection via antegrade Bretschneider's cardioplegia were intiated, the distal anastomoses in coronary artery bypass grafting were performed in cases with an indication for concomitant revascularization. Next, the LA was opened by a standard left atriotomy, and the MV was analyzed according to the technique of Carpentier [1983]. Monopolar endocardial RF ablation lesions were

Table 1. Characteristics of the 152 Mitral Valve Patients with Concomitant Permanent Atrial Fibrillation (AF)*

Age, y	68 ± 9 (36-89)
M/F sex, n (%)	83/69 (55/45)
NYHA class	3.0 ± 0.3 (2-4)
LVEF, %	54 ± 13 (26-88)
pAF duration, y	5.8 ± 6.1 (0.5-33)†
LA diameter, mm‡	57 ± 6 (43-71)
Relevant TR (≥grade 2), n (%)	64 (42)
Significant CAD, n (%)	32 (21)
Severe AV disease, n (%)	5 (3)
Anticoagulation therapy (coumarin), n (%)	102 (67)
History of failed interventional AF ablation, n (%)	7 (5)
History of failed DC cardioversion and antiarrhythmic medication, n (%)	54 (36)
Etiology of MV disease, n (%)	
Degenerative	73 (48)
Rheumatic	44 (29)
CMP	13 (9)
Ischemic	10 (7)
Endocarditis	1 (1)
Combined	11 (7)
EuroSCORE§	6.9 ± 2.4 (2-12)

*Data are presented as the mean ± SD (range) unless otherwise indicated. NYHA indicates New York Heart Association; LVEF, left ventricular ejection fraction; pAF, permanent AF; LA, left atrium; TR, tricuspidal regurgitation; CAD, coronary artery disease; AV, aortic valve; DC, direct current; MV, mitral valve; CMP, cardiomyopathy.

†Data are presented as the mean ± SD (range). Median (interquartile range), 4.0 years (1.5-8 years).

‡The LA diameter at discharge (12 ± 9 days after surgery) was 53 ± 4 mm.

§EuroSCORE is a scoring system for evaluating the predicted risk of cardiac

created prior to 2002 with the Thermaline device (n = 19) and subsequently with the Cobra device (n = 133), an almost identical system (Boston Scientific Corporation, San Jose, CA, USA). RF ablation was performed at 100 W for 2 minutes, with a local temperature set at 70°C. The first lesion isolated the right pulmonary veins from the inferior right pulmonary vein to the superior right pulmonary vein via the left atriotomy. The left pulmonary veins were isolated with a semicircular ablation line close to the inferior left pulmonary vein and another ablation line around the superior left pulmonary vein. These ablation lines were connected in the middle by a short transverse lesion across the posterior LA wall (Figure 1). Thermal injury to the esophagus was avoided by passing a dry compress behind the LA before energy delivery, performing the ablation only under direct view during conventional open heart valve surgery, removing the transesophageal echocardiography probe during the ablation procedure, adapting the flexible ablation probe to the tissue without pressure, setting the local temperature at only 70°C, and excluding cachectic patients [Geidel 2004]. The LA appendage was sutured

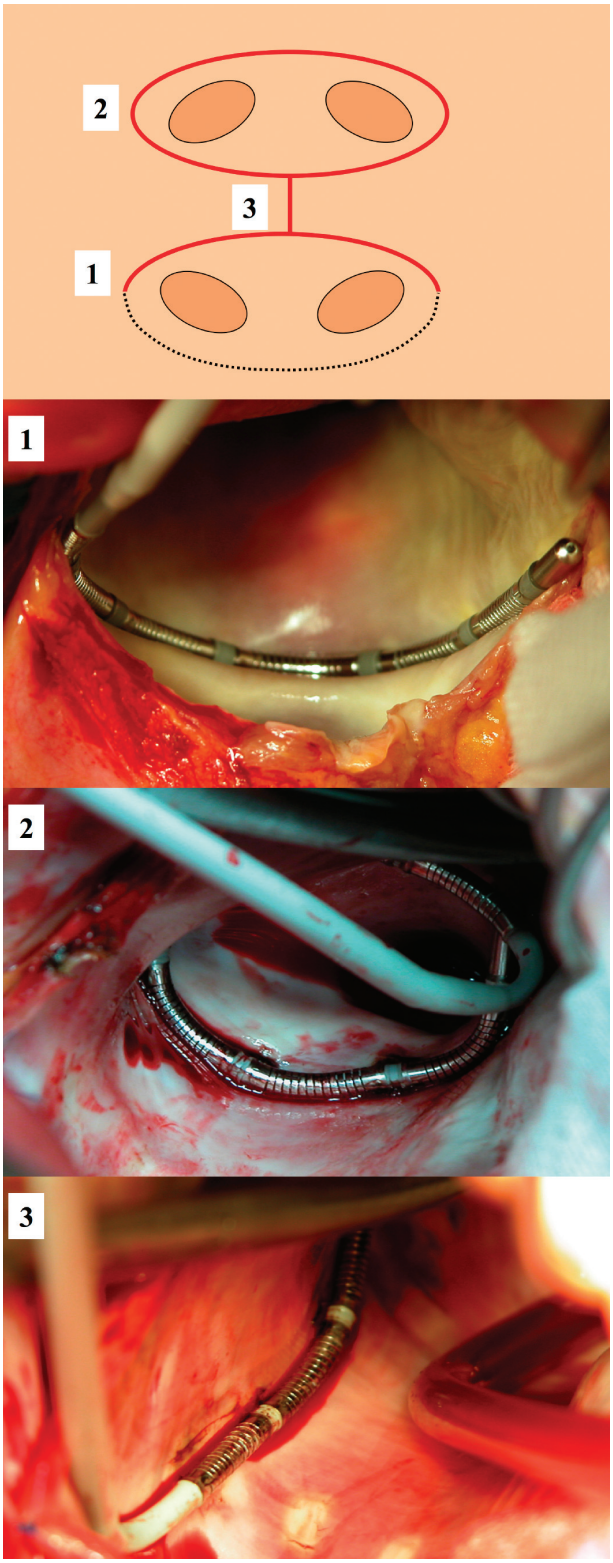

Figure 1. Lesion pattern of monopolar radiofrequency ablation using the Cobra device. Isolation of the right pulmonary veins via the left atriotomy (1), ablation of the left pulmonary veins (2), and connecting lesion on the posterior left atrial wall (3).

from the endocardial side in cases with LA enlargement (LA diameter >55 mm). Then, the MV was repaired or replaced, depending on the MV pathology. All other procedures were performed after LA closure (Table 2).

Perioperative Management of Cardiac Rhythm and Follow-up

An experienced cardiologist routinely conducted transthoracic echocardiographic and standard 12-lead electrocardiographic (ECG) examinations at the time of patient admission and before discharge. LA size was assessed by evaluating the LA diameter (anteroposterior diameter in a parasternal axis view at end-systole). An LA >55 mm was deemed large (mean LA of AF and MV patients in our institution between February 2001 and February 2005, 56 mm), and a LA diameter ≤55 mm was considered small. A tricuspidal regurgitation grade of ≥2 as documented by transthoracic echocardiography was an indication to perform concomitant tricuspid valve (TV) repair. Amiodarone administration consisted of an initial intravenous 300-mg bolus before the end of cardiopulmonary bypass, followed by an infusion of 900 mg/day for 3 days. Then, oral administration of amiodarone was begun (5 × 200 mg/day up to 7-10 g, depending on body weight, followed by 1 × 200 mg/day for 3 months).

Table 2. Surgical Data (n = 152)*

Procedures, n	
MV repair	36
MV repair (reoperation)	1
MV repair, ASD closure	2
MV repair, ASD closure, CABG, TV repair	5
MV repair, ASD closure, TV repair	1
MV repair, AV replacement	1
MV repair, AV replacement, TV repair	1
MV repair, CABG	8
MV repair, CABG, TV repair	9
MV repair, TV repair	31
MV repair, TV repair (reoperation)	3
MV replacement	23
MV replacement (reoperation)	1
MV replacement, ASD, TV repair	1
MV replacement, AV replacement	2
MV replacement, AV replacement, TV repair	1
MV replacement, CABG	10
MV replacement, myxoma resection	1
MV replacement, TV repair	12
Operation time, min	192 ± 27
CPB time, min	130 ± 26
ACC time, min	93 ± 18
Ablation time, min	8.0 ± 1.5
Total ablation procedure time, min	11.9 ± 3.0

*Data are presented as the mean ± SD unless otherwise indicated. Mitral valve (MV) repair procedures, 66% (n = 100); MV replacement, 33% (n = 52). ASD indicates atrial septal defect; CABG, coronary artery bypass grafting; TV, tricuspid valve; AV, aortic valve; CPB, cardiopulmonary bypass; ACC, aortic cross-clamping.

In cases of thyroid disease, amiodarone incompatibility, or another contraindication for amiodarone administration, sotalol was administered as an alternative (an initial 10-mg intravenous bolus followed by 1 mg/kg over 24 hours and daily oral administration of 2-3 doses of 40-80 mg for 3 months). Bradycardia persisting for more than 10 days prompted termination of amiodarone/sotalol administration. Bradycardia persisting for 14 days was an indication for implantation of a permanent pacemaker. Direct current cardioversion was recommended in cases of early recurrence of AF during the hospital stay after patient saturation with amiodarone/sotalol and after a transesophageal echocardiography evaluation had excluded intracardiac thrombosis. Patients were monitored continuously during the initial period of saturation with antiarrhythmic drugs and in cases of AF recurrence or bradycardia, first in the intensive care unit and then in an intermediate care unit. Heparin was administered after the resolution of postoperative bleeding. Patients who underwent MV repair or received an MV bioprosthesis received coumarin for 3 months, and patients who had mechanical valves received lifelong anticoagulation therapy. All patients were reevaluated with standard 12-lead ECG and a clinical examination prior to hospital discharge (8 ± 1 days) and at the follow-up examinations early (3 ± 1 months) and late (41 ± 24 months) after surgery. In addition, a standard 24-hour ECG registry evaluation was performed.

Statistical Analysis of the Data

Quantitative preoperative and operative data were described as the mean ± SD or as the median (interquartile range), if appropriate. Qualitative data were presented as frequencies. An exploratory data analysis was performed for data assessment, and no adjustments were made for multiple tests. Univariate and multivariate binary logistic regression models were used to evaluate pAF recurrence and persistence early and late after surgery. We included both continuous measurements and parameter values grouped according to clinically relevant values (eg, LA size, ≥55 mm versus <55 mm; pAF duration, ≥5 years versus <5 years). Qualitative data were also compared with chi-square tests (the Fisher exact test and the McNemar test). Changes in the New York Heart Association (NYHA) class were investigated with the Friedman test (Monte Carlo method; upper bound of 99% confidence interval given). All *P* values were the product of 2-tailed tests and interpreted nominally. *P* values <.05 were considered statistically significant. Analyses were performed with SPSS for Windows (version 11.5.2.1; SPSS, Chicago, IL, USA).

RESULTS

Ablation was applied concomitant to isolated MV surgery in 61 patients (40%), and additional surgical procedures were performed in the remaining 91 patients (60%) (eg, TV repair and/or coronary artery bypass grafting). The MV was repaired in 100 patients (66%) and replaced in 52 patients (33%). All other relevant surgical data are summarized in Table 2.

The early mortality rate (<30 days) was 2.6% (1 noncardiac and 3 cardiac deaths; at the time of death, 2 patients were in SR, and 2 had AF). During the hospital stay, 39 of 60 patients with early AF recurrence underwent direct current cardioversion procedures. Sixteen (41%) of these cardioversion procedures were successful, and 3 patients converted to SR spontaneously. Four patients underwent pacemaker implantation for persistent bradycardia, and a short episode of postoperative self-terminating atrial flutter was observed in 1 patient. At the time of hospital discharge (12 ± 9 days), 109 (74%) of 148 patients were in SR.

Early and Late Follow-up

The survival rates at the 3- and 41-month follow-ups were 95% and 92% (140 of 152 patients), respectively (6 cardiac and 6 noncardiac deaths). The mean survival time was 79 months (95% confidence interval, 76-82 months). The SR conversion rate was 75% (109 of 145 patients), and 73% (102 of 140) of the patients at the late (41-month) follow-up had stable SR (between the early and late follow-ups, 5 survivors experienced recurrence and persistence of pAF, and 1 patient converted to a stable SR spontaneously). Ninety percent of the patients in SR at discharge also were in SR at the late follow-up. A univariate logistic regression analysis identified preoperative pAF duration and preoperative LA size as variables predictive of cardiac rhythm late after surgery ($P = .0002$, and $P = .0003$, respectively). Permanent long-term AF at the time of surgery was detected as an incremental risk factor for the return of AF after ablation ($P = .001$, at the time of discharge for grouped parameter values; $P = .0001$, at 3 months, continuous measurement [$P = 0.00000043$, grouped values]; $P = 0.0002$, at 41 months, continuous measurement [$P = .00000016$, grouped values]). A larger LA size was another risk factor (3-month follow-up: $P = .0005$ [grouped parameter values], and $P = .0005$ [continuous measurement]; 41-month follow-up: $P = .0005$ [grouped parameter values]; $P = .0003$ [continuous measurement]). Seventy-five (91%) of 82 patients with preoperative pAF of <5 years' duration and 57 (88%) of 65 patients with a small LA size were in stable SR late after surgery. A multivariate binary logistic regression analysis demonstrated that the 2 best predictor variables for a prognosis of long-term rhythm were the cardiac rhythm at discharge and at 3 months after surgery ($P = .021$, and $P = .00002$, respectively). The variables of sex, preoperative left ventricular ejection fraction, associated coronary artery or TV disease, an underlying etiology of MV disease, and age had no statistically significant influence on postoperative cardiac rhythm. However, at the time of discharge, 59% of the patients with AF had been at least 70 years old at the time of surgery, compared with 43% of the patients in SR ($P = .096$), and at the late follow-up, 55% of the patients with AF had been at least 70 years old at the time of surgery, compared with 41% of the patients in SR ($P = .181$). At the late follow-up, 96 (69%) of 140 patients needed no anticoagulation therapy (all 38 patients with AF and 6 in SR postoperatively still required anticoagulation therapy). Functional class improved significantly after surgery (NYHA class decreased from 3.0 ± 0.3 to 1.5 ± 0.5; $P = .006$), particularly when a stable SR was achieved (1.4 ± 0.5 in SR patients versus 1.9 ± 0.3 in pAF patients). The SR group had 68% (69/102) of the patients in NYHA class 1 and 33% (33/102) in class 2, and the group of patients with AF recurrence had 13% (5/38) of the patients in NYHA class 1 and 87% (33/38) in class 2 ($P = .039$).

DISCUSSION

Surgical Practices for Curing AF during MV Surgery

The incidence of AF is well known to be particularly high in patients with severe MV disease, and the presence of persistent AF deteriorates the prognosis after surgery [Benjamin 1998; Benussi 2000; Jessurun 2000; Melo 2000; Geidel 2004]. AF has been demonstrated to originate from foci located predominantly in the area near the LA–pulmonary vein junction and is maintained by activation-wave fronts of reentrant circuits [Moe 1962; Allessie 1985; Wijffels 1995; Haissaguerre 1998]. This is the reason why many surgeons who use ablation techniques during MV surgery generally closely follow the principles of the Maze procedure, including pulmonary vein isolation, reduction of atrial size, and interruption of reentrant circuits with "complex" lesions/incisions [Cox 1996; Sueda 1997; Benussi 2000; Melo 2000; Khargi 2003]. RF energy has become the most widely used energy source for this type of surgery (cryogenic application and microwaves have been described as alternatives [Benussi 2000; Khargi 2003; Knaut 2003]) and is frequently used in a monopolar fashion with endocardial and/or epicardial ablation techniques with approximately comparable and successful results. The potential deficiency of monopolar endocardial application is that transmurality is not "guaranteed" and that rare but fatal complications may occur if lesions are too deep [Gillinov 2001]. During MV surgery, however, the advantage of endocardial monopolar application is that the LA has already been opened and the lesions can be set while directly viewing the atrial tissues. Many surgeons believe that an ideal lesion set should combine minimal invasiveness and simplicity with high reproducibility and satisfactory success rates. However, the answer to the question of whether such a lesion pattern is actually applied in practice must be a negative one: The mechanisms of the initiation and maintenance of AF obviously vary and are related to individual electrophysiological/structural changes, particularly when AF has already become permanent [Li 1999; Goette 2000; Kawara 2001]. At present, some of the relevant questions involve which lesion set can be used as a basic procedure and which patients require additional approaches (eg, completion according to the individual pathologic/electrophysiological changes in the patient).

Evaluation of Results and Perspectives for Improving Current Results

Our results with pAF ablation surgery are generally in line with the experience of other investigators; that is, our surgical ablation approach for the majority of patients involves interrupting the AF wavelets sustained by foci

located predominantly inside the pulmonary veins and providing additional rhythm protection, including medical therapy, in the absence of AF [Roy 2000; Benussi 2000; Jahangiri 2006; Bakir 2007]. However, our data demonstrate that an established SR actually remains stable over a long period of time, almost 4 years. Although our lesion set did not follow what others have recommended (eg, we omitted a lesion to the mitral annulus), we observed postoperative atrial flutter, which some investigators expect to occur more often when this line is omitted, in only 1 patient. We achieved a satisfactory success rate compared with the results of other authors, a finding that from our point of view argues against performing additional lesions in every MV patient with pAF.

Published data have indicated that the preoperative LA size is relevant to the short-term success of monopolar endocardial RF ablation surgery [Geidel 2004]; however, whether LA size itself was the critical issue remained uncertain. The thesis was that parallel structural morphologic and electrophysiological changes in the atrial tissues are more marked in cases with progressive enlargement and/or hypertrophy of the atria [Li 1999; Goette 2000; Kawara 2001]. Such electrical and anatomic atrial remodeling is supposed to be the reason behind what has been described as "atrial fibrillation begets atrial fibrillation" [Wijffels 1999]. In cases of small LA size, it was conceded that the encircling lesions might encompass relatively larger portions of the LA, compared with the lesions in patients with a larger LA. In such cases, reentrant circuits in the LA tissue may be interrupted more frequently. Besides, a reduced LA size has been described to be advantageous for restoring SR in patients with chronic AF and a large LA following MV surgery [Jansz 2003]. However, although our patients were approximately a decade older than the patients of other studies [Benussi 2000; Melo 2000], the surgery was well tolerated. In particular, we observed no case of esophageal injury [Gillinov 2001]. We interpret this result to be due to the precautions taken to avoid this fatal complication.

Apart from LA size, the duration of preoperative pAF especially influenced the prospects for establishing a stable SR, a finding in line with data from an international registry, which termed LA size to be "the best predictor of [ablation] success" in a heterogeneous group of MV patients with permanent or other forms of AF and reported an attrition rate of only 2.6%/year for AF recurrence [Melo 2006]. However, we suppose that the independent incremental risk factor that predicts the failure of AF surgery probably is not LA size (or pAF duration) itself, but the cellular morphologic/electrophysiological changes correlated with progressive LA enlargement and pAF duration. It is our thesis that these factors are of significant relevance, in general, for the success of ablation surgery for AF.

The decision to perform ablation for pAF during MV surgery normally depends on a risk/benefit assessment of the procedure and the preferences of the individual patient. Our data may be helpful for assessing whether concomitant ablation surgery can be successful in a particular MV patient. The inclusion/exclusion criteria we have described for ablation are currently followed in our institution; however, if a patient is at a high risk for failure of ablation surgery, we are more reticent and sometimes refrain from ablation, particularly when the clinical situation is complex. In cases with good preoperative conditions (small LA size, short pAF duration), we strongly recommend ablation surgery, because our results have demonstrated that a stable SR can be restored in approximately 90% of these patients. In cases of presumed advanced damage, however, it would also be of great interest to be able to identify highly diseased myocardium outside of the area of the LA–pulmonary vein junction, perhaps via histologic analysis and/or fibrillation electrograms, and then use this information to selectively ablate/isolate all structures potentially responsible for the arrhythmia. From our point of view, the concept of individualized and selective ablation/isolation of all diseased parts of the atria may be an alternative to present strategies. However, even if postoperative analysis can document remarkable regional differences (eg, pronounced interstitial fibrosis, distinct fragmentation), a device that can localize specific relevant changes in the individual patient and enable ablation of all relevant regions outside the area of the LA–pulmonary vein junction in real time is still not available. At present, the described approach of using "blind" monopolar RF ablation enables the restoration of a stable SR in the majority of pAF patients who undergo MV surgery, particularly when the LA is still small and the duration of pAF is short.

CONCLUSIONS

The data allowed evaluation of early and late results of a monopolar endocardial RF ablation concomitant to MV surgery in patients with a pAF duration of 0.5 to 33 years. We have demonstrated that an SR conversion rate of >70% overall and approximately 90% in patients with good preoperative conditions (ie, small LA size, short pAF duration) can be achieved and that the SR remains stable for nearly 4 years. Preoperative LA size and pAF duration were identified as useful variables for predicting the success rate of monopolar RF ablation in MV patients. The preoperative presence of long-term pAF and a larger LA size must be considered risk factors for the failure of ablation surgery for pAF in these patients.

Study Limitations

The study consisted of a heterogeneous group of MV patients with respect to the type of cardiac pathology. Furthermore, the 152 patients constituted a selected group, thus limiting the conclusions that can be drawn from the evidence. The data were not evaluated under randomized conditions. The study was not designed for patients with paroxysmal AF or with pAF persisting for less than 0.5 years. It also was not designed to investigate the results of other ablation approaches. For rhythm evaluation, we conducted no 7-day Holter monitoring and performed only a single 24-hour ECG registry evaluation. Furthermore, the late follow-up did not include an echocardiographic investigation of LA function, limiting the completeness of the data. Post-operative anticoagulation management was not dependent on the size and contractility of the atria.

REFERENCES

Allessie M, Lammers WJEP, Bunke FI, Hollen J. 1985. Experimental evaluation of Moe's multiple wavelet hypothesis of atrial fibrillation. In: Zipes D, Jalife J, eds. Cardiac electrophysiology and arrhythmias. New York, NY: Cruno and Straiton: 265-75.

Bakir I, Casselmann FP, Brugada P, et al. 2007. Current strategies in the surgical treatment of atrial fibrillation: review of the literature and Onze Lieve Vrouw Clinic's strategy. Ann Thorac Surg 83:331-40.

Benjamin EJ, Wolf PA, D'Agostino RB, Silbershatz H, Kannel WB, Levy D. 1998. Impact of atrial fibrillation on the risk of death: the Framingham Heart Study. Circulation 98:946-52.

Benussi S, Pappone C, Nascimbene S, et al. 2000. A simple way to treat chronic atrial fibrillation during mitral valve surgery: the epicardial radiofrequency approach. Eur J Cardiothorac Surg 17:524-9.

Carpentier A. 1983. Cardiac valve surgery: the "French correction." J Thorac Cardiovasc Surg 86:323-37.

Cox JL, Schuessler RB, Lappas DG, Boineau JP. 1996. An 8½-year clinical experience with surgery for atrial fibrillation. Ann Surg 224:267-75.

Geidel S, Laß M, Boczor S, Kuck KH, Ostermeyer J. 2004. Monopolar and bipolar radiofrequency ablation surgery: 3-year experience in 90 patients with permanent atrial fibrillation. Heart Surg Forum 7:E398-402.

Gillinov AM, Pettersson G, Rice TW. 2001. Esophageal injury during radiofrequency ablation for atrial fibrillation. J Thorac Cardiovasc Surg 122:1239-40.

Goette A. Staack T, Röcken C, et al. 2000. Increased expression of extracellular signal-regulated kinase and angiotensin-converting enzyme in human atria during atrial fibrillation. J Am Coll Cardiol 35:1669-77.

Haissaguerre M, Jais P, Shah DC, et al. 1998. Spontaneous initiation of atrial fibrillation by ectopic beats originating from the pulmonary veins. N Engl J Med 339:659-66.

Jahangiri M, Weir G, Mandal K, Savelieva I, Camm J. 2006. Current strategies in the management of atrial fibrillation. Ann Thorac Surg 82:357-64.

Jansz P, Bennetts J, Wilson M, Spratt P, Farnsworth A. 2003. Restoration of sinus rhythm following mitral valve surgery with left atrial reduction in patients with chronic atrial fibrillation [abstract]. Annual Scientific Meeting of the Society of Cardiothoracic Surgeons of Great Britain and Ireland, 2003. Abstract 38.

Jessurun UR, van Hemel NM, Kelder JC, et al. 2000. Mitral valve surgery and atrial fibrillation: is atrial fibrillation surgery also needed? Eur J Cardiothorac Surg 17:530-7.

Kawara T, Derksen R, de Groot JR, et al. 2001. Activation delay after premature stimulation in chronically diseased human myocardium relates to the architecture of interstitial fibrosis. Circulation 104:3069-75.

Khargi K, Kuschkowitz F, Deneke T, et al. 2003. Cooled-tip-radiofrequency ablation is a distinct different technique to treat chronic atrial fibrillation: a prospective study including 138 patients [abstract]. Thorac Cardiovasc Surg 51(suppl 1):S52.

Knaut M, Tugtekin SM, Gulielmos V. 2003. Microwave ablation as an additional procedure for treatment of permanent atrial fibrillation in patients with cardiosurgical disease [abstract]. Thorac Cardiovasc Surg 51(suppl 1):S51.

Li D, Fareh S, Leung TK, Nattel S. 1999. Promotion of atrial fibrillation by heart failure in dogs: atrial remodeling of a different sort. Circulation 100:87-95.

Melo J, Andragao P, Neves J, et al. 2000. Endocardial and epicardial radiofrequency ablation in the treatment of atrial fibrillation with a new intraoperative device. Eur J Cardiothorac Surg 18:182-6.

Melo J, Berglin E, Sie H, et al. 2006. Surgery for atrial fibrillation in mitral patients with and without additional procedures: results at 5 years from an international registry. Paper presented at the 86th AATS Annual Meeting; 2006 April 29–May 3; Philadelphia, Pa, USA.

Moe GK. 1962. On the multiple wavelet hypothesis of atrial fibrillation. Arch Int Pharmacodyn Ther 140:183-8.

Roy D, Talajic M, Dorian P, et al. 2000. Amiodarone to prevent recurrence of atrial fibrillation. N Engl J Med 342:913-20.

Sueda T, Nagata H, Oriashi K, et al. 1997. Efficacy of a simple left atrial procedure for chronic atrial fibrillation in mitral valve operations. Ann Thorac Surg 63:1070-5.

Wijffels MCEF, Kirchhof CJHJ, Dorland R, Allessie MA. 1995. Atrial fibrillation begets atrial fibrillation: a study in awake chronically instrumented goats. Circulation 92:1954-68.